Short Term Scientific Mission Report
University of Nottingham (UN)
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1. Purpose of the STSM

Comparison between two sniffer based methane emissions measurement methods and data handling systems in UK and Poland.

2. Description of the work carried out during the STSM

On the first day I visited the respiration chambers. Each of them can accommodate four sheep or one cow. The open circuit measurement with NDIR (Non Dispersive Infra Red) analyser is used and also the sniffer measurement nozzles are placed in the chamber to allow simultaneous measurement with this method. The calibration is done by three gas mixtures: pure nitrogen and two levels of methane in the air.

Next, I was introduced to the methane data analysis system. Team of prof. Garnsworthy uses Methane Peak Analyser written by Adam Garnsworthy to select and analyse every eructation peak. The program counts also peak frequency in every milking, as well as mean peak value and times of rises and falls of the peaks. I got familiar with raw data and data processed by the program.

On the second day I went to the University farm. The staff introduced me to different aspects of farm management including nutrition, milking system, rearing and others. The facility possess equipment used to different experiments, i.e. feed bins used for measuring dry matter intake (DMI) and gas emissions measuring system. The gas emissions measuring system is installed in the milking robot (Lely Astronaut A3). The nozzle is placed in feed bin, the air goes through it and humidity filter into the analyser which is placed in a box on the robot. There are four installations. There are some differences between this system and the system used by PULS. Polish installation has dust filter and heated air duct. This makes humidity filter not necessary. The installation is cleaner inside. Main difference is analyser type (NDIR: Non Dispersive Infra Red at UN vs FTIR: Fourier Transform Infra Red at PULS).

NDIR has small sample cell and enables measuring of one specific gas only. Therefore, the UN installation has to have two analysers for two gases (CH_4 and CO_2). The FTIR analyser can estimate emissions of many gases simultaneously and there is no problem of humidity thanks to heated air duct. However, the FTIR method has one major disadvantage which is longer reaction time. Another problem is price which is higher for FTIR installations.

On the third day, I have had interesting discussions with UN team members about data collecting and processing system. The main issue is to join data from gas analysers loggers with the data from Lely system. This is done in multiple steps, with the use of programs such as Loggy Software (industrial program from analyser producer), SQL servers, MS Excel and finally the Methane Peak Analyser. This system is similar both at UN and at PULS.

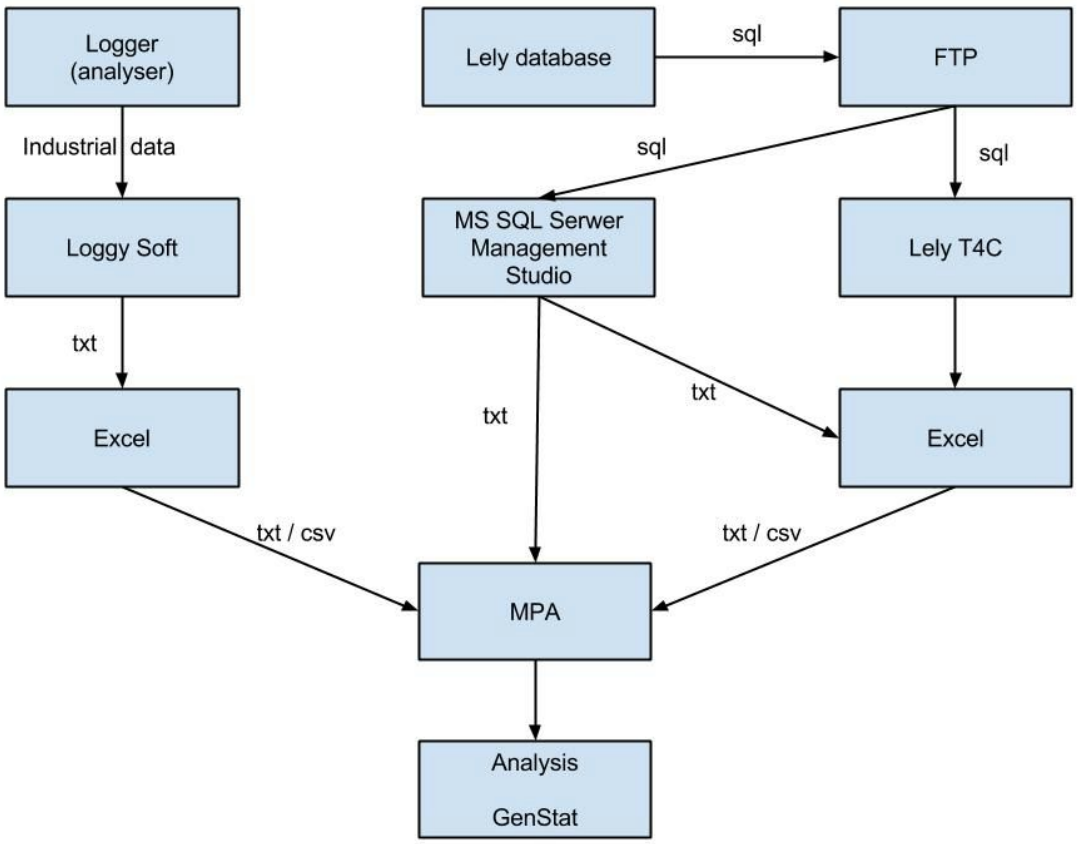

Figure1. Data processing system

The reaction time problem was also discussed this day. Each measurement system has its own TC (Time Constant). TC is the time which the system needs to reach the 90% level of the actual gas concentration. The animal emits gas by leaps, in the eructation peaks. The actual concentration has its maximum very fast as well as decreases very fast. The

measured concentration is parabolic. The time between start of gas emission by animal and reaching 90% of its concentration by the system is TC. When TC is shorter than the length of eructation peak, everything is measured properly. But when it is longer, not whole height of the peak is captured and underestimation occurs. In the chart below, the first peak is underestimated and the second one is properly measured. Thus, the shorter TC, the better.

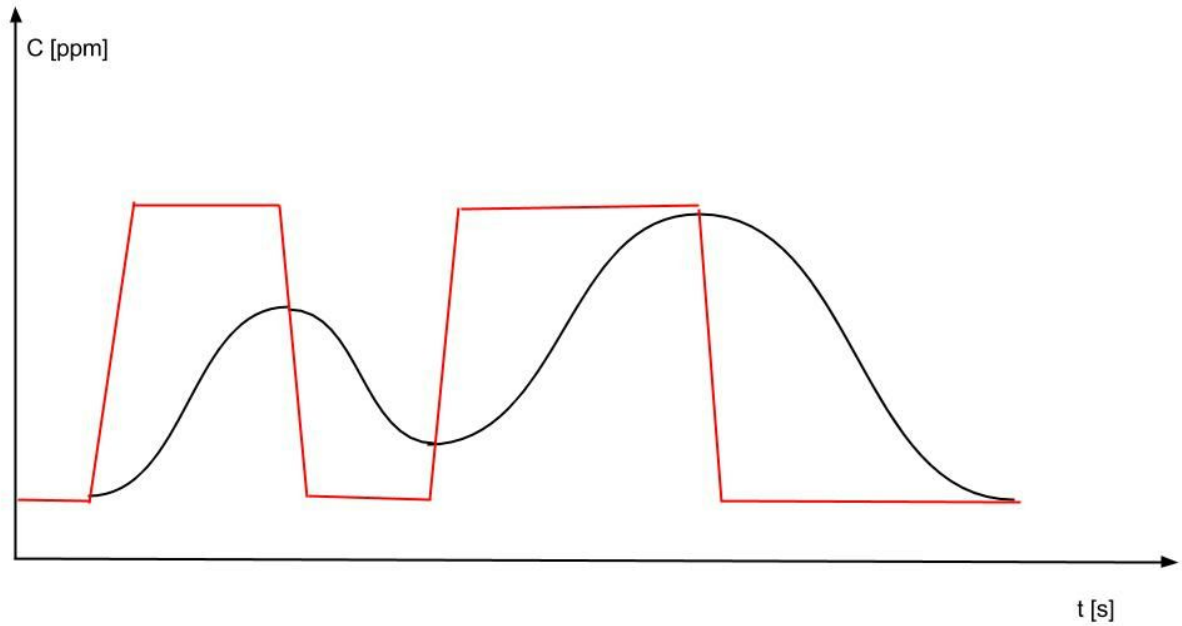

Figure 2. TC problem. The red line - actual gas concentration, the black line - measured gas concentration

The FTIR analyser used by PULS has long TC (~90 seconds) compared to british NDIR (~14 seconds). Thus, this problem has to be taken under consideration. Proper estimation of peak height can be made using the following equation:

$$\mathbf{FP = (1 - e^{-t/TC})}$$

where: FP is fraction progress after time of t, TC is time constant, e is the Euler–Mascheroni constant ~ 2.718

TC and e are known, and t is the time of peak rise. Thus, the fraction progress is a percentage value representing fraction of maximum height the peak would achieve if the system had enough time to measure it. With this help every peak can be analysed properly. Another solution is to increase the sampling rate. In PULS device it is 1.0 l min^{-1} while in

another FTIR systems with higher sampling rate (e.g. 4.0 l min^{-1}) TC was reported under 20s.
In the last two days I was focused on data analysis. The results are discussed in the next point.

3. Description of the main results obtained

I intended to estimate repeatability and between-animal CV (coefficient of variation) with both methods (integral from peaks and average) on data from both sources (PULS and UN). I received some data from Professor Phil Garnsworthy as well as Methane Peak Analyser (MPA) program with its code. In the average method, the average gas concentration from every milking was established. Every animal was treated as a group. The one-way ANOVA was conducted on collection of averages milking concentration and repeatability was estimated from ANOVA components. The CV was estimated classically (standard deviation divided by mean). In the integral method, the peaks from every milking were selected. Peak was recognized when next three consecutive concentration measurements were increasing. The area (integral) under each peak was calculated with the level from start of the each peak subtracted. Then the area under all peaks together was multiplied by frequency of the peak (MEIm). This procedure was done for each milking. Further, the set of MEIm's was analysed similar as in the average method. The integrals were estimated in MPA and the repeatability and CV were estimated in the R software. My initial intention was to rewrite the MPA program for my own and adjust it to PULS data. This approach turned to be very time-consuming (it is still in progress). Therefore, I decided to format PULS data similar to UN and put it into MPA. I was succesful in this approach, however the MPA is suited to 1s interval measurements and PULS system intervals are at the level of 5s. Because of this, the peaks were not properly analysed and I had to abandon this method. Finally I analysed the PULS data with the average method as well as UN data with both methods.

Table 1. Analysis results for PULS (PL) and UN (UK) data

	Average		**Integral**
	FTIR (PL)	NDIR (UK)	NDIR (UK)
Repeatability	37,12%	30,52%	21,01%
CV (between animals)	36,02%	44,34%	47,51%

The table 1 shows that PULS data analysed by the average method is more reliable than UN data analysed by both methods. However, all values are not at satisfying level. In case of PULS data, it could be due to simple analysis method where no constant effects (such as lactation number, day of the lactation, hour of the day, DMI etc. effects) were taken into account. In case of UN data, additionally to narrow time period of the analysed data.

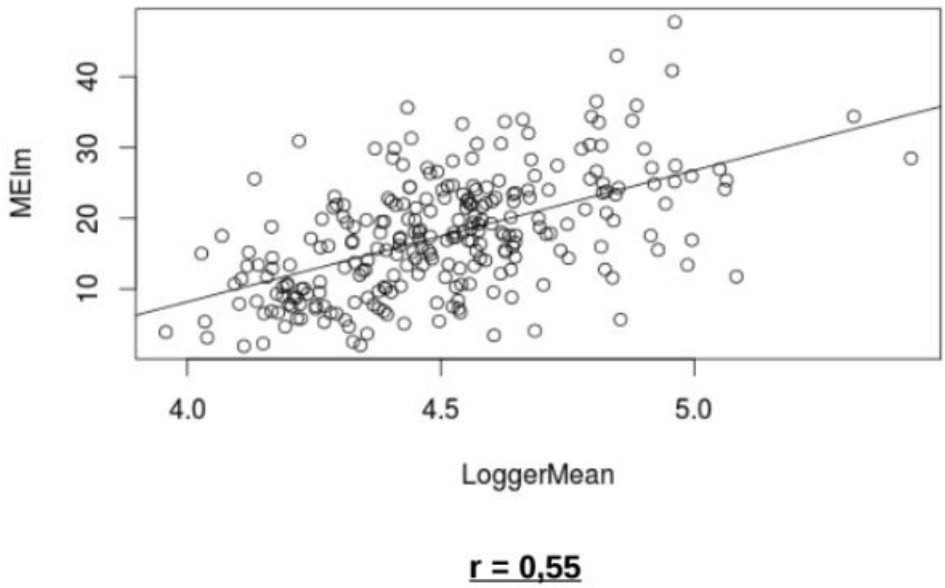

Figure 3. The correlation between average (LoggerMean) and integral (MEIm) methods

Finally the correlation between the average and integral methods was calculated for the UN data only. The correlation of 0.55 between these two methods is not as high as expected. However, the integrals analysis subtracted the base level from every peak and the average analysis did not accounted for the base level. The method of analysis that accounts for the base level is currently under development at PULS.

4. Summary

The visit at the Sutton Bonington Campus of the University of Nottingham was very productive and rich in new experiences. It was good to get to know another approach to methane data analysis. Big part of the new knowledge gained during this STSM will be or was already used by PULS team to improve our data collecting and processing system. Most important example is the eructation peaks analysis which will be added as another data processing method to our research. This will make our results more comparable to results from the UN team and show opportunities for future collaboration between UN and PULS which addresses a primary aim of the Methagene COST Action.